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REVIEW OF 1949 SOVIET PERIODICAL LITERATURE ON METEOROLOGY

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Research in many fields of meteorology was conducted in 1949 in the USSR. The periodical literature surveyed indicates that a great deal of interest is being shown in the structure and dynamics of the upper layers of the atmosphere and in the twilight method of studying these layers. Since the worth of the twilight methods depends upon the accuracy with which the scattering of light by various media can be measured, many papers are concerned directly or indirectly with this problem. No such emphasis was observed in any other field of meteorology, although the problem of atmospheric turbulence was studied rather intensively.

A review (1) of the theory and development of the twilight method of studying the upper layers of the atmosphere is given by N. M. Shtaude, one of the men instrumental in its development. The main points of Shtaude's survey follow: In 1915, V. G. Fesenkov published a work in which it was shown that the density distribution of air up to heights of 100-200 kilometers could be studied by measuring the brightness of the sky at twilight. In 1923, Fesenkov published a mathematical theory of this method. The method has been developed and refined through the intervening years and many important results have been obtained by Soviet scientists using the twilight method. Shtaude and V. P. Vetchinkin confirmed the presence of high temperatures, of the order of 300 degrees Kelvin and higher, in the upper layers of the atmosphere shortly before this was established by Lindeman and Dobsen by meteorite observations. The most promising use of this method would be as an aid to more powerful methods of observing the stratosphere (meteorite observations, rockets, etc,).

The equipment of a twilight station is very simple, consisting of only a chronometer or accurate clocks and a photometer for measuring the brightness of the sky in a given direction. The simplest photometer is a small tube with out lenses moving along a photographic plate, film, or photoelement. Such a photographic or photoelectric eye, in conjunction with clocks, is sufficient

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for studying the upper layer of the atmosphere if the data obtained is processed carefully. These observations could be verified by means of direct observations with the aid of rocket missiles. The method is now used in the work of the Laboratory of Atmospheric Optics, Geophysical Instiute, Academy of Sciences USSR, and the Abastumanskiy Observatory of the Academy of Sciences Georgian SSR. The USSR is the only nation using this method to any considerable degree at present, although some attention is given it in France, Sweden, and Czechoslovakia.

Shtaude feels that the method is not used in the US because Hulburt cast doubt upon Fesenkov's work of 1923 and maintains that Hulburt used in his calculations an atmospheric structure which is now considered incorrect and which has in fact been disproved by direct observations of sounding rockets in the US.

Shtaude devotes a separate article (2) to a more detailed discussion of this problem. According to this study, there are two possible types of atmospheres: one in which the influence of secondary scattering increases rapidly with increase in the angle between the sun's vertical and the line connecting the sun and the center of the earth, or one in which this influence increases, reaches a maximum, and then begins to decrease. Hulburt's conclusion that it is impossible to study atmospheric layers above 65 kilometers by the twilight method, Shtaude admits, is fully applicable to an atmosphere of the first type, but adds that an atmosphere of the second type would permit study by the twilight method up to 300 kilometers. The development of the twilight method depends upon which of the two types describes the earth's atmosphere.

Shtaude feels that the earth's atmosphere must belong to the second type because temperatures at altitudes up to 160 kilometers calculated from zenith twilight intensity observations at the Abastumanskiy Observatory compare favorably with those obtained by the aurora borealis and ionospheric observation methods. The discrepancy in the temperature estimated by the twilight method and those measured by sounding rockets for altitudes 70-100 kilometers, the author explains, is due to the fact that the molecular weight was assumed to be constant in the twilight method. Shtaude proposes that below 70 kilometers, the molecular weight is the same as on the earth's surface, while above 82 kilometers it is still a constant, but considerable smaller. The author feels that the twilight method has proved itself sufficiently so that the problem of organizing mass twilight observations to study the stratosphere in time and in space can be discussed and thinks this should throw light upon many problems of geophysics and the physics of the sun.

Shtaude also published a paper (3) on the illumination of the atmosphere from terrestrial sources of light. The following problem is discussed: Given a light source and an observer situated within or outside a certain scattering medium, determine the brightness of scattered light in a given direction. The scattering medium is assumed to be of spherical form with or without a certain opaque mucleus. The optical density of this medium is a function only of the distance from the center. These assumptions are approximately true for the majority of celestial bodies and for the earth's atmosphere in particular.

According to Shtaude, a number of problems of astrophysics and atmospheric optics reduces to the solution of this problem. Knowing the law for the variation of optical density with distance from the center, one could, by solving this problem, find the illumination of planetary nebulae at various distances from the latter; one could also find how much illumination of the earth's atmosphere is caused at night by large cities (Moscow, Paris, New York) for any height. The author suggests that the problems which could be solved include the evaluation of the influence of city lights on astronomical observations or the possible influence of meteor flights on the illumination of the night sky.

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The wife of Academician V. G. Fesenkov is also conducting research in this field (4, 5). In a work (4) on the fundamental optical properties of the atmosphere, i.e., the optical thickness of the atmosphere or the coefficient of transparency and the indicatrix of scattering, Fesenkova proved that the linearity of the relative aureoles (ratio of illumination from the aureole to that from the sun) is a more sensitive criterion of the stability of optical properties than is the linearity of the dependence of the logarithm of solar radiation on atmospheric mass. No confirmation was found, however, for the opinion held by Fesenkov, N. N. Kalitin, and Abbot, that a singular relationship exists between the transparency of the atmosphere and the brightness of the aureole around the sun and that variation in the first value can be judged by variations in the second. All aerological data used in this study was obtained from airplane flights and radiosonde observations of the Alma-Ata Geophysical Observatory. All synoptic data was obtained from the Bureau of Forecasts, Kazakh Administration of the Hydrometeorological Service.

In a second paper (5), Fesenkova found good correspondence for the brightness of the sky at various heights measured at two observation points. The logarithm of the brightness was found to be a linear function of the height above 20 kilometers. The zenith brightness of the sky at a height of 20 kilometers is approximately one-tenth of that on the earth's surface. The zenith brightness of the sky in the daytime is the same as on a moonless night (10^{-8} stilbs) at a height of about 130 kilometers.

Other works on scattering of light were published by G. V. Rozenberg and K. S. Shifrin. In his paper (6), Rozenberg pointed out that the methods now in use for calculating the polarization of light undergoing second-order scattering (Tikhanovskiy, Ahlgrimm, Soret) have major deficiencies. The usual solution is based on the use of a vector-parametric description of light flow. The author introduces another method based on the use of an ellipsoid of polarization, which can be employed for the case of purely molecular scattering. Rozenberg used this latter method to study daylight and twilight scattering of sunlight in the zenith direction due to molecular scattering and found that the degree of polarization of multiple-scattered light is very high.

Shifrin proved that an error exists in Mie's formulas for calculating the intensities of the transverse and longitudinal components of scattered light (7). In comparing the calculations using his own formula of the intensity of light scattered by a spherical particle with Blumer's calculations from Mie's formulas, Shifrin noted that his figures were only one half those obtained by Blumer. The author established that in Blumer's work, as in all others using Mie's formulas e.g., the recent works of Ruedy, and Paranjepe, Naik, and Vaidya, there is an error which causes all results to be twice the correct value. This error does not influence the form of the indicatrix of scattering or the degree of polarization of the scattered light, since it causes a proportional increase of all intensities. The error is important, however, in comparing the absolute values of the calculated intensities with the experimental, and in using the results of the tabulation of Mie's formulas to calculate the coefficients of scattering. According to Shifrin, the multiplier "$\frac{1}{2}$" should be introduced into the formulas to obtain correct results.

Twilight measurements were also used in a study by Rodionov and Pavlova (8) relating to the structure of the stratosphere. This study resulted from the work of the El'brus Complex Expedition of the Academy of Sciences USSR in 1948. The authors maintain that the study of the radiation of sodium should throw light upon the ascending currents in the stratosphere which spread the layers of sodium up to heights of 80 to 100 kilometers. The results of photoelectric twilight measurements at 2,200 meters at Adyl-Su, Caucasus, indicated that sodium is present not only at altitudes of 60 kilometers and higher, but also at considerably lower altitudes.

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N. B. Divari (9) reported on observations of the night sky. Such observations are often used to arrive at conclusions concerning the upper layers of the atmosphere. Divari's report can be summarized as follows: A special, radioactive, lensless night-sky photometer No 2, constructed by Fesenkov, was used in the observations. The observation points were chosen so as to exclude the disturbing influence of the light of large cities and to secure good transparency of the atmosphere. The 27 curves obtained for the brightness of the sky at the beginning and end of night showed that a characteristic drop of brightness occurs at these times.

In summarizing the research on the upper layers of the atmosphere, Soviet periodical literature for 1949 seems to indicate a marked emphasis on the twilight method, possibly to the disadvantage of other methods, such as meteorite trails or rockets. This may be due to the fact that studies of the latter type are not reported in overt source material. This possibility is somewhat strengthened by a statement of I. A. Khvostikov (10), a leading Soviet meteorologist, as follows: "In 1947, the US press and radio, particularly the 'Voice of America,' raised an uproar over the 'wonderful' results of the measurements of temperatures in the upper layers of the atmosphere obtained during experimental flights of V-2 rockets into the stratosphere. Actually, however, the results obtained in no way changed the picture of temperature distribution obtained previously by the twilight, radio, and the aurora borealis methods."

Two articles (11, 12) involved applications of atmospheric optics other than the twilight method. The first article (11), by Ye. A. Polyakova, reports the results of a study that was undertaken with two main purposes; namely, to review the basic ideas concerning the mechanism of the formation of glow colors in order to determine whether consideration of single Rayleigh scattering in the theory is sufficient to obtain glow colors which are observed under actual conditions for high atmospheric transparency; and to clarify the degree to which real changes of transparency in the lower atmospheric layers beyond the horizon influence variations of the glow colors.

With regard to the first problem, calculated distributions of energy in the light striking the eye from four points of the twilight sky in the sun's vertical for angular heights of 0, 2.5, 5, and 10 degrees and for a depression of 4 degrees showed good correspondence with the glow observed, thus demonstrating the correctness of the theoretical representation for the mechanism of glow-color formation.

The second problem was studied in order to evaluate N. I. Kucherov's proposal that glow observations be used in synoptic practice. Kucherov's proposal follows the hypothesis that the type of glow is dependent on the degree of transparency of the lower layers of the troposphere beyond the horizon in the region of a given point and is founded on a statistical comparision of the glow types with the synoptic type of air mass in the same region. Polyakova's calculations, however, showed that the lower layers of the real atmosphere beyond the horizon up to an altitude of approximately 5 kilometers pass very little of the sun's radiation in the visible part of the spectrum; therefore, the possible variations in transparency conditions of the lower atmospheric layers beyond the horizon cannot explain the variety of glow types observed. Although the author does not consider it possible to judge the character of an air mass beyond the horizon by observations of the glow in the visible part of the spectrum as Kucherov proposed, she does not wish to belittle the importance which further development of the study of glow phenomena may have for investigating atmospheric properties. She suggests that it may be possible to use glow phenomena for sounding the lower atmospheric layers if a section of the infrared spectrum can be found for which the lower atmospheric layers are sufficiently transparent.

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Rozenberg's article (12) discusses a possible application of atmospheric optics to geodesy. According to Rozenberg, accurate geodesic measurements are made difficult by the lack of methods for determining the errors introduced by atmospheric refraction. Some time ago, I. A. Khvostikov suggested that measurements of the variation in the angle of refraction with wave length be used to determine the angle of refraction, pointing out that these measurements might be made successfully by using a method similar to Michelson's method of measuring the diameters of stars. Determination of the angle of refraction according to its variation assumes a priori knowledge of its dependency upon wave length. Khvostikov derived a simple formula for this dependency by using an analogy between refraction in the symmetrical trajectory of a ray and refraction in a prism. However, according to Rozenberg, the applicability of the analogy with the prism to the real atmosphere was not proven. Moreover, he asserts that there are cases where this analogy cannot be applied and that use of the method first requires the establishment of the conditions of its applicability and the finding of practical convenient criteria for the fulfillment of these conditions. Rozenberg establishes experimental criteria and demonstrates the applicability of the method to the real atmosphere.

Results on measuring turbulence under natural conditions were obtained in the Laboratory of Atmospheric Turbulence of the Geophysical Institute, which was organized in 1946 through the initiative of Academician A. N. Kolmogorov (13). Valuable material on measurements of turbulence in the surface-air layer and in the free atmosphere was obtained by expeditions in 1947 and 1948. Turbulence at high altitudes was studied jointly with the Central Aerological Observatory, by use of thermoanemometers in balloon flights. In these flights, the difference in velocities at close points was registered for the first time and data was obtained on micro-movements in the free atmosphere up to heights of 3,000 meters. It was established that there are "turbulized" zones, alternating with zones of complete calm, in the atmosphere. New equipment is being developed in the laboratory for the study of the microstructure of the temperature field in the atmosphere and the processing of data previously obtained in this study is being continued.

The latter project is probably being undertaken to check A. M. Obukhov's newly developed concept of the structural function of a temperature field (14). The idea of a structural function of a temperature field, Obukhov states, was suggested by, and is analgous to, Kolmogorov's concept of the structural function of a wind velocity field. Obukhov found that this structural function of a temperature field, which is the mean square of the temperature difference for two observation points, is proportional to the distance between the points to the two-thirds power when the points are fairly far apart, assuming local-isotropic turbulence. The author feels that his rough calculations must be made more accurate by special measurements of rapidly pulsating temperatures at closely spaced points in the atmosphere (from several centimeters up to a meter)

Obukhov's concept was used in a study (15) by V. A. Krasil'nikov of the effect of temperature pulsations on the reception of ultrashort waves. The substance of Krasil'nikov's report follows: Temperature inhomogeneities caused by a field of chance wind velocities mix to produce temperature pulsations. These temperature non-homogeneities are considered as optical lenses. Those non-homogeneities, for which the variations in refractive index are less than the wave length, cause scattering of the ultrashort waves, while those for which the variations are greater than the wave length change the curvature of the wave front, causing distortion and fluctuations in signal strength at the receiver. Thus, the variations in signal strength are the total effect of the lens action of the local non-homogeneities. The fluctuations in the logarithm of the amplitude were found (a) to be proportional to the characteristic of the field of temperature pulsations, (b) to increase progressively with distance between transmitter and receiver, and (c) to increase with decrease in wave length. An expression was derived for the correlation between the equations for the signal

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strength at two receivers located at the bases of a triangle with the transmitter at the apex. The mean square of the fluctuations in phase difference at the two receivers is proportional to the frequency, to the characteristic of the field of temperature pulsations, to the length of the base of the triangle to the 5/6 power, and to the square root of the distance from the transmitter to the center of the base. The theoretical formulas for variations in signal strength were checked with the experiments of Waynick and MacLean and were of the correct order of magnitude. The check could not be complete since the characteristic of the field of temperature pulsations has not been measured in the atmosphere, but only preliminarily evaluated by Obukhov. The formulas for phase fluctuations could not be checked because of lack of experimental data. Development of this theory, Krasilnikov believes, will be of interest not only for the propagation of ultrashort waves in a disturbed atmosphere, but also from a purely geophysical standpoint.

The effect of thermal non-homogeneities on another physical quantity is discussed in Arabadzhi's work (16) on the damping of sound in the lower layers of the atmosphere. He derived an expression for the coefficient of damping, which was checked by using Gol'tsman's value of 0.5 degree centigrade for the variation of air temperature in the free atmosphere. For a frequency of 1,000 cycles, a value of 6.10^{-5}/cm was obtained for the coefficient of damping from the formula Experimentally, Sieg had obtained a value of 3.10^{-5}/cm for the same frequency for still air in the free atmosphere.

Another fertile field in Soviet periodical literature on meteorology for 1949 was wind, which was the object of study in five reports. Monin's study (17) of wind distribution with respect to height for the case of curvilinear isobars is a generalization of a work by Bagrov, who solved this problem for an ideal fluid. In Monin's work, the atmosphere is considered as a viscous incompressible fluid, and its stationary motion relative to a rotating earth in a field of curvilinear isobars is studied. The solution, the author states, may also be applied to quasi-stationary processes and permits determination of the influence of viscosity on the variation of the pressure field with weight.

In a second work (18) in this field, mountain-valley winds are considered as the motion of air from thermal causes over a relief which is smooth enough for the theory of the boundary layer to be applied but not smooth enough for a parametric dependency to be assumed for all elements of motion on the coordinate directed along the slope. Gutman's highly theoretical treatment of the system of equations for the local winds produces functions which describe the vertical distribution of temperatures and velocity components over the top of a mountain range at night or over the middle of its associated valley in the daytime.

The equations of heat balance proposed by Academician V. V. Shuleykin for the theory of monsoons were solved by Sekerzh-Zen'kovich in a third paper (19) on wind. The cases of an elliptical island and a parabolic peninsula were studied to determine the influence of capes on the intensity of a monsoon field. It was theoretically determined that the intensity of a monsoon field is greatly increased against a sharp cape.

V. I. Arabadzhi, in a fourth paper (20) on this field, attempts to explain Dobson's measurements which established that the ozone content in the atmosphere has a definite connection with the weather, i.e., it is maximum over a cyclone and minimum over an anticyclone. Arabadzhi's explanation follows: Given atmospheric pressure decreasing with height, gradients of the electric field of a cloud system close to breakdown exist at an altitude of about 25 kilometers. These gradients provide a corona discharge, which causes additional formation of ozone over cyclones. It is characteristic that the greatest increase in the ozone content of the atmosphere is observed in the rear of cyclones, indicating the strong electric fields in this direction. Thus, the increase in the ozone content of the atmosphere over cyclones is due to the electric field of the cloud system of cyclones.

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A fifth study (21) in this field, of importance in forecasting displacements of air masses and fronts, has been previously reported in detail (00-W-6247/49).

Only two reports were submitted in 1949 in the field of practical meteorology, on (22) on forecasting droughts along the Volga and another (23) on the activity of the T'ien Shan Station. Bova's report on forecasting droughts in southeastern USSR represented a statistical study of the meteorological conditions observed in this area in previous droughts. The author established a direct relationship between the appearance of spring and summer droughts in the southeastern USSR and the following meteorological phenomena: high solar radiation in autumn and spring; the number of hours of sunshine in March; a dry autumn and little snow in the winter; a considerable rise in the air temperature from winter to spring; and an early or normal spring. The coefficient of correlation was calculated for each factor separately and an over-all coefficient of 0.88 was obtained. Most of the coefficients were calculated from data covering a period of 50 years, with the exception of the data for solar radiation in autumn and spring. Actinometric data over a sufficiently long period was available only for Saratov (Institute of Grain Economy of Southeastern USSR), and that covered only 10 years.

The T'ien Shan Station, founded by the Institute of Geography in 1947, is conducting systematic observations on the climate of the region as a whole and on representative sectors of the various mountainous regions of T'ien Shan (23). According to the report, these complex studies are being made for the first time, and thus a considerable part of the station's activity is given to developing methodology. All studies are accompanied by extensive laboratory tests and various types of analyses, most of which are made in the stations' laboratories.

Three reports were submitted in 1949 in the field of radiation and temperature, two on solar radiation (24, 25) and one (26) on the temperature in the earth's atmosphere. Solar radiation from the standpoint of astronomy was the subject of a study (24) by B. M. Rubashev. According to Rubashev, L. A. Vitel's had previously shown that the range of zonal transfer in the earth's atmosphere is closely connected with prolonged variations of solar activity. Similarly, the concurrence of the intensification of solar activity with an increase in the intensity of Jupiter's bands, discovered by A. M. Bakharev (astronomer, Stalinabad Observatory) in 1937, confirms the supposition that the intensity of zonal circulation in Jupiter's atmosphere is directly connected with solar activity. Rubashev states that intensification of latitudinal transfer on Jupiter causes sharper demarcation of the cloud belts making up the zonal circulation of this planet. Thus, he states, the relative darkness of Jupiter's bands is presumed to be a new, highly promising index of solar activity.

In a second report (25) on radiation, V. G. Kastrov showed that Moller's formula for the amount of solar radiation absorbed by atmospheric water vapor is in error, According to the author, the difference in the results calculated by Fowle, Hoepler, and Kimball based on Fowle's experimental data from those calculated by Moller's formula has long been the subject of speculation. A recheck of Moller's calculations, using the same method and the same data, with the exception of the absorption bands, gave a new formula which agreed completely with the results of Fowle, Hoepler, and Kimball's calculations. Moller gave the formula as $dI = 0.172\ (mw)^{0.303}$; where m is the optical mass of the atmosphere and w is the water-vapor content; the correct formula; according to Kastrov, is $dI = 0.156\ (mw)^{0.294}$.

O. S. Berlyand's article (26) on the temperature gradient in the earth's atmosphere includes a brief review of Soviet work on this problem. I. A. Kibel' originally solved the problem of the average yearly temperature gradient by studying the equations of energy flow with long and short-wave radiation and

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turbulent mixing in the vertical direction as parameters. Kibel' later extended the solution to the nonstationary case, having generalized the theory for arbitrary heights. Finally, Ye. N. Blinova solved the more complex problem of the distribution of temperatures with respect to geographical latitude and with respect to height, having generalized the equations to include lateral (horizontal) mixing. In his study, Berlyand attempts to make the results relating to the upper layers of the atmosphere more accurate by precise definition of some of the parameters of the problem. His results agree almost perfectly with those of Kibel' up to 9 kilometers, and beyond that point differ slightly.

Microclimatology was the subject of two reports (27, 28) published in 1949, N. M. Topol'nitskiy's study (27) of the violation of the logarithmic law of the lapse rate in the microclimatic layer represented an experimental check of a theoretical formula. The formula derived by M. I. Budyko was checked by thrice-daily observations using a thermocouple from May to September over a period of 2 years at heights of 0, 5, 10, 20, 40, 100, and 200 centimeters above the earth's surface. Most of the observations above 20 centimeters followed the logarithmic law, while most of those below 20 centimeters were not governed by the law. The author found three types of violations, all occurring most frequently in the "active layer" (the layer from the ground up to 40 centimeters), namely: (a) microinversions; (b) dew formation; and (c) a reduction in the magnitude of the gradient.

Results of an attempt to model atmospheric phenomena were reported by Shifrin, Gordon, and Faynshteyn (28). A cylindrical steel chamber was filled with a low concentration of smoke and the transparency of the smoke to light was continuously recorded by a selenium photocell mounted on one wall of the chamber. The authors believe that the coefficients of diffusion measured for the steel chamber approximate those which are present in the atmosphere when "stable stratification" is present close to inhomogeneities of the microrelief, such as buildings or vegetation. These inhomogeneities, it is stated, cause horizontal temperature changes and consequently chaotic convection.

Only one paper (29) on atmospheric electricity was published in 1949. This Imyanitov's study of the horizontal component of the electric field in the atmosphere, involved electrostatic experiments with the electric field analgous to Gauss's experiments with the earth's magnetic field, and can be summarized as follows: The electric field near the earth is usually considered as a purely vertical field having three components, namely, the field formed by the potential difference between the earth and the Heaviside layer, the field formed by clouds and ionic accumulations in the higher layers of the atmosphere, and the fields from the space charge close to the earth. Recently, however, a horizontal component of this field was discovered. In this study, methods and instruments were developed to measure the intensity of this horizontal component. The measurements showed an unexpectedly high value for the horizontal component, reaching several volts per centimeter and sometimes exceeding the value for the vertical component. This strong horizontal field close to the earth's surface may explain the inclined lightning bursts which originate from the earth. Measurements which would separate the vertical and horizontal fields would make it possible to solve one of the most important problems of atmospheric-electric measurements, namely, the separation of the component of the field due to charges in the higher atmospheric layers from the component connected with the space charge close to the earth. The method of measurement proposed may also be of value in measuring the field in the free atmosphere and especially in clouds where horizontal fields greater than vertical fields can be expected.

N. N. Shiskin authored a general article (30) on clouds and their formation, rain, conditions of rain formation, and thunderstorm electricity. Shiskin states that Bergeron's concept of rain as ice particles which have fallen through warm air masses from two-phase clouds (water drops and ice particles) cannot explain rain from the water clouds characteristic of tropical zones. The author has studied the problem of the growth of drops in a water cloud by coagulation from the standpoint of the different falling velocities of various-sized drops.

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